



Transportation Network Topologies



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Outline

1. Transformation and scalability
2. *A notional* air transportation network topology
3. Technologies and Scalability in Air Transportation Systems

***Modern developments in network theory
offer new ways to think about
complex, adaptive systems.***



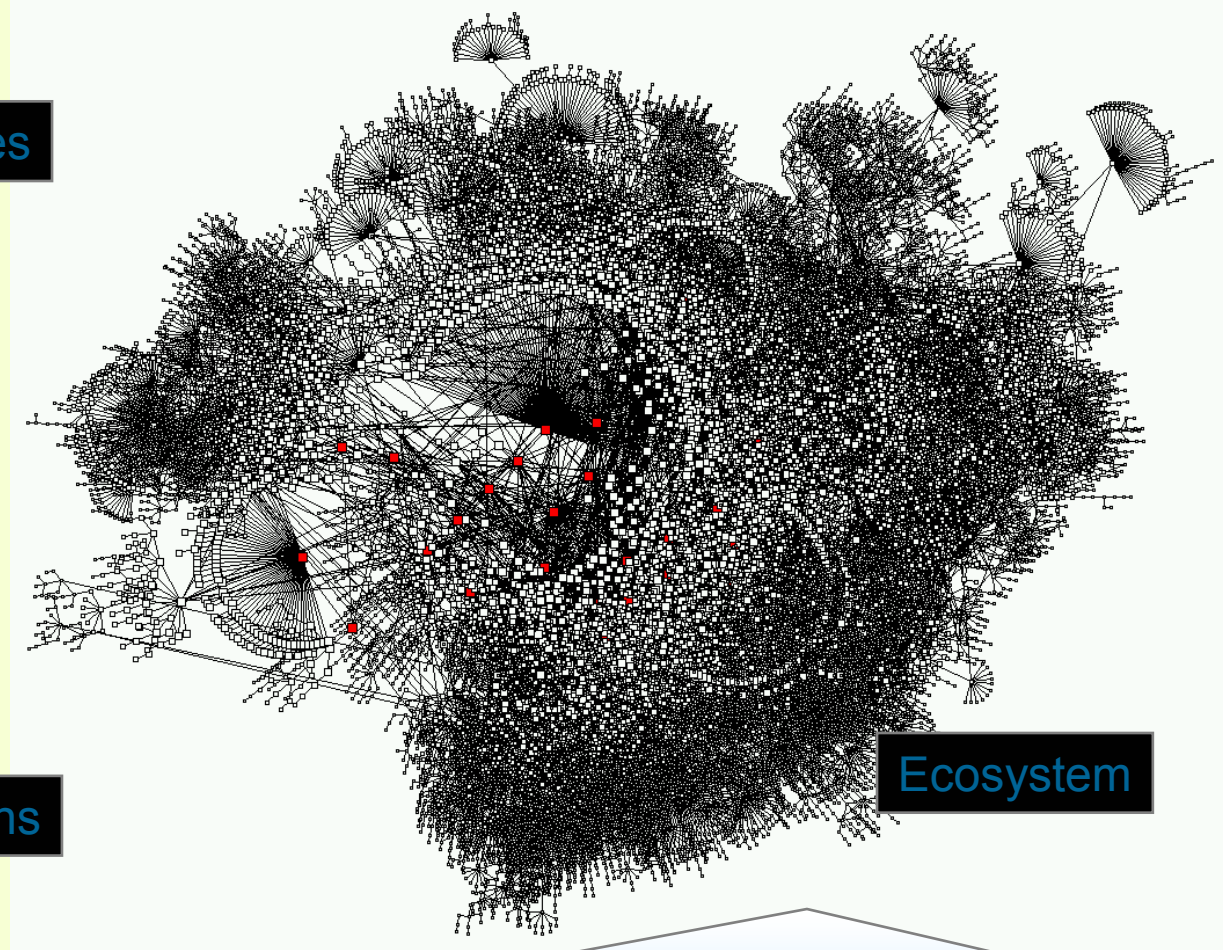
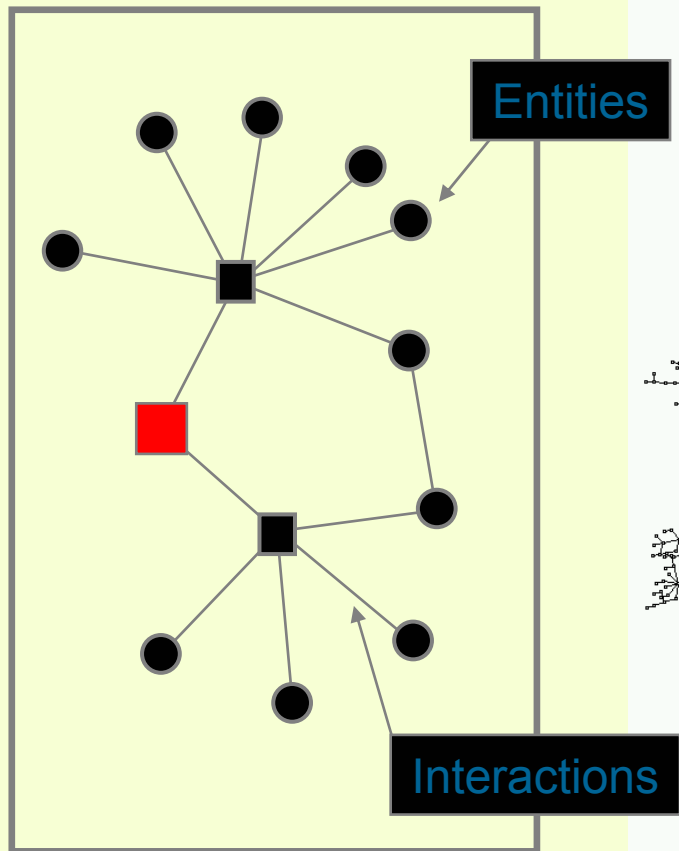
Why Transformation?

- **The current aviation system does not scale to meet future needs related to***
 - Aircraft
 - Airports
 - Airspace
 - Commerce and Business models
 - Environmental considerations
 - Security and safety considerations
- **Evolution and modernization plans do not lead us to the changes needed beyond 2015**
- **Transformation requires change across government agencies**
- **The results of transformation produce new business models, new regulatory models, as well as new uses of airspace, airports, and aircraft**
- **The outcome of transformation is to enable scalability to meet the nation's needs in commerce, mobility, security , and safety**

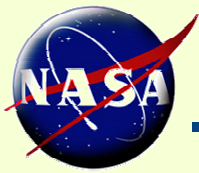
***From NRC Report (2003) and the President's Commission Final Report (2002)**



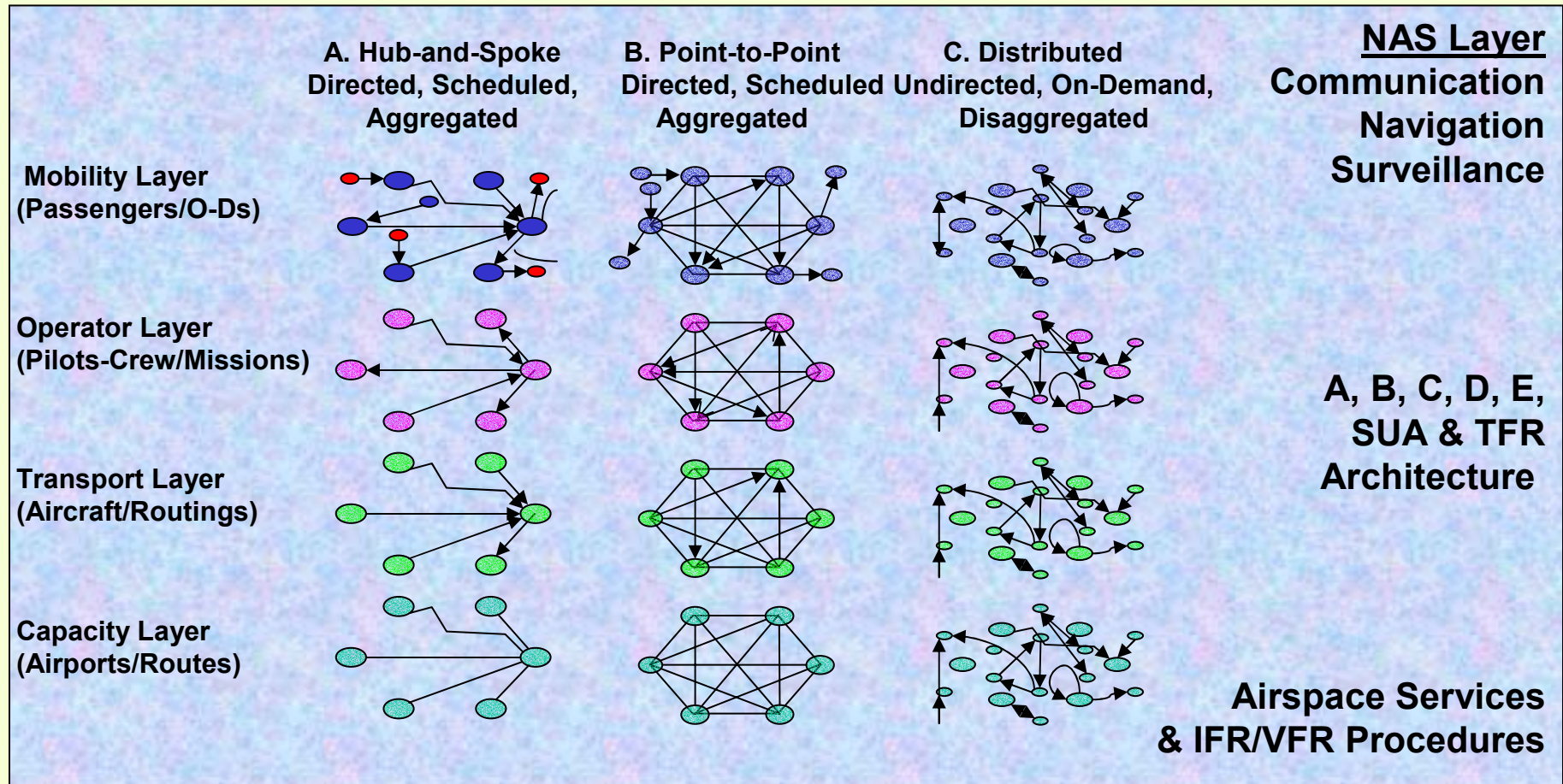
An Ecosystem Illustrates The Need for Topology



Individual Actions lead to Complex Ecosystem



A Proposed Air Transportation Network Topology

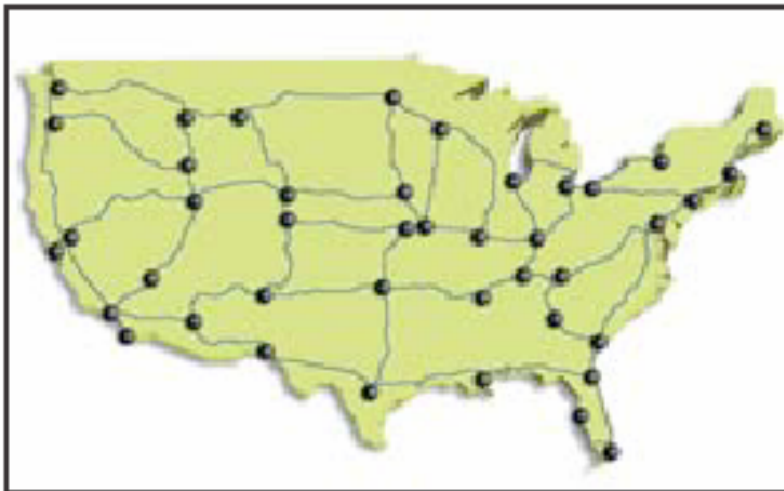




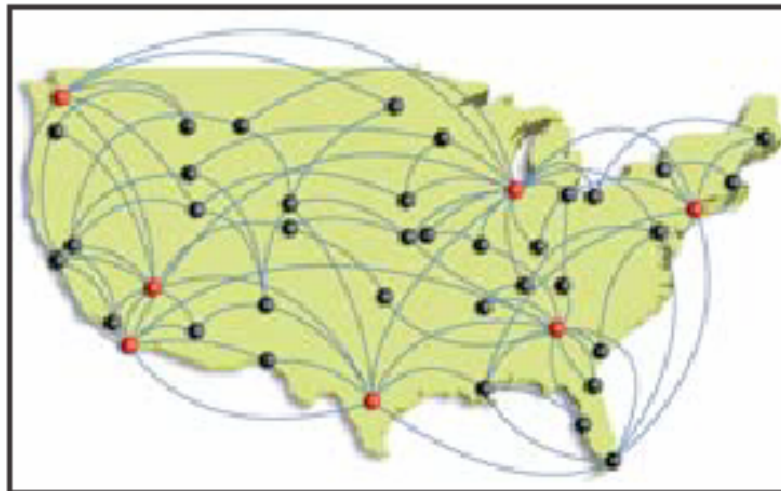
Network Types

(Barabasi & Bonabeau, Scientific American May 2003)

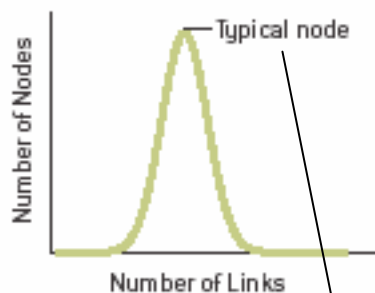
Random Network



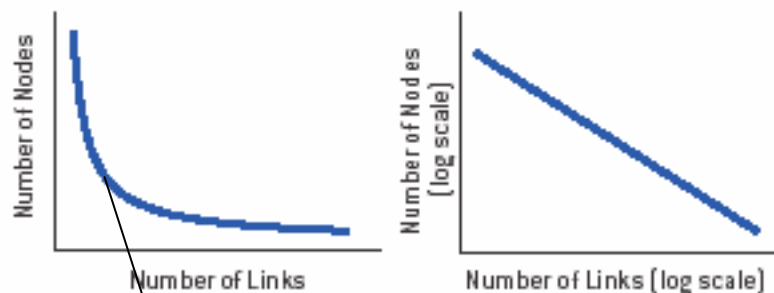
Scale-Free Network



Bell Curve Distribution of Node Linkages



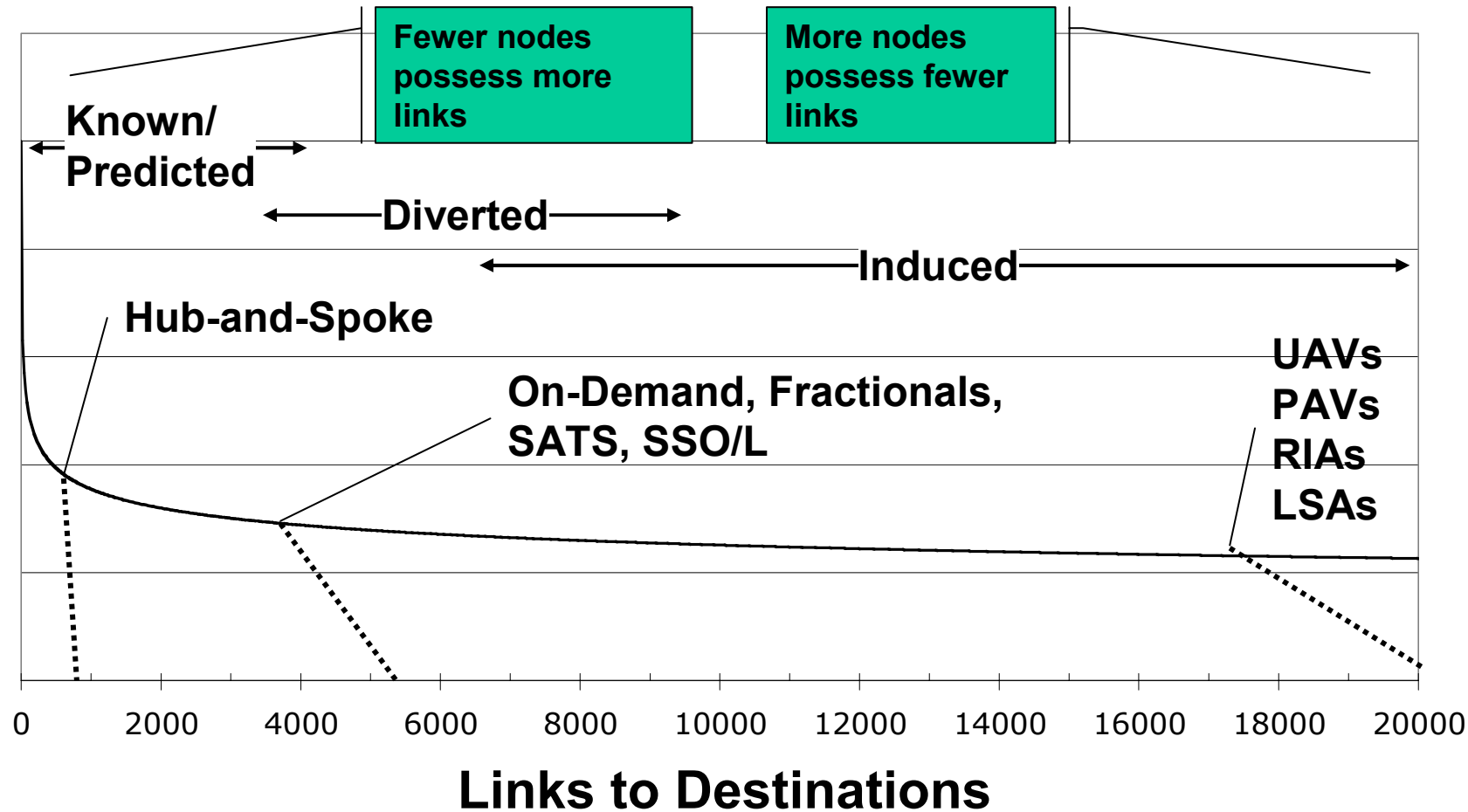
Power Law Distribution of Node Linkages



A node exists which has a characteristic scale of the network

No node exists which has a characteristic scale of the network

Power Law Distribution in Air Transportation (Physical & Transport Layers)



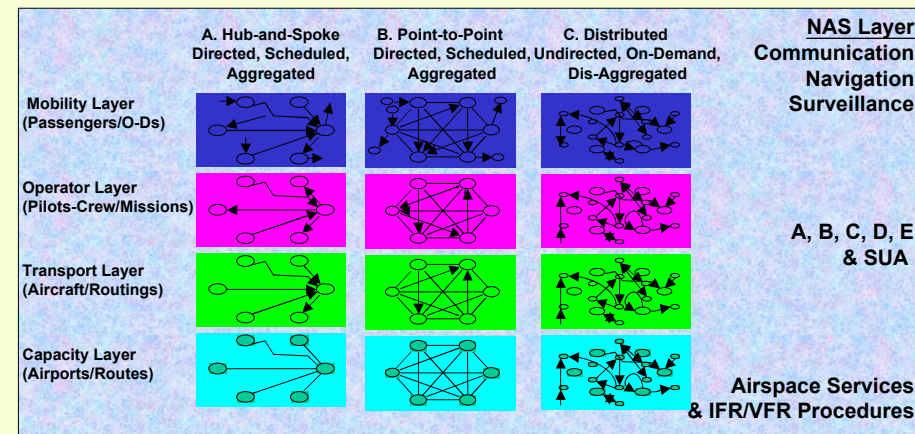
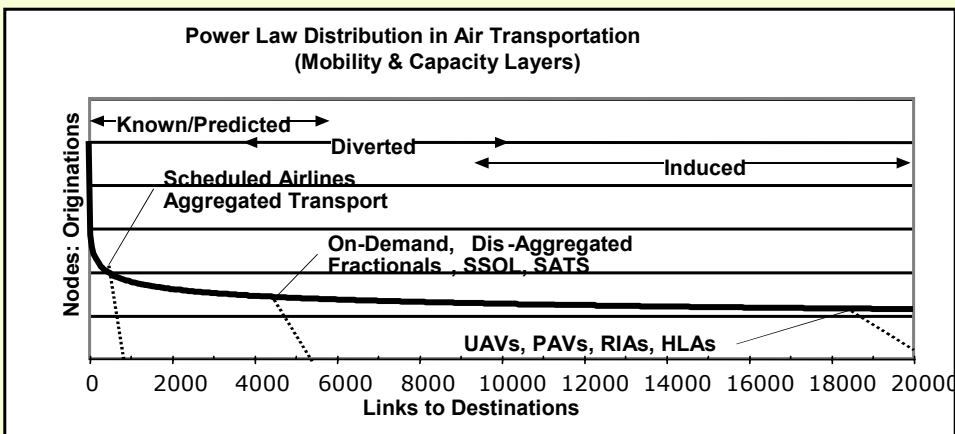
Examples of Scalable Behaviors in Air Transportation Topology

- Physical layer (airports-infrastructure) supports growing access to more runways in more weather
- Transport layer (new aircraft) supports growing access to more markets/communities
- NAS layer (airspace architecture & procedures) supports ubiquitous airspace access and services



Topologies for Air Transportation Networks

As framework for primal questions

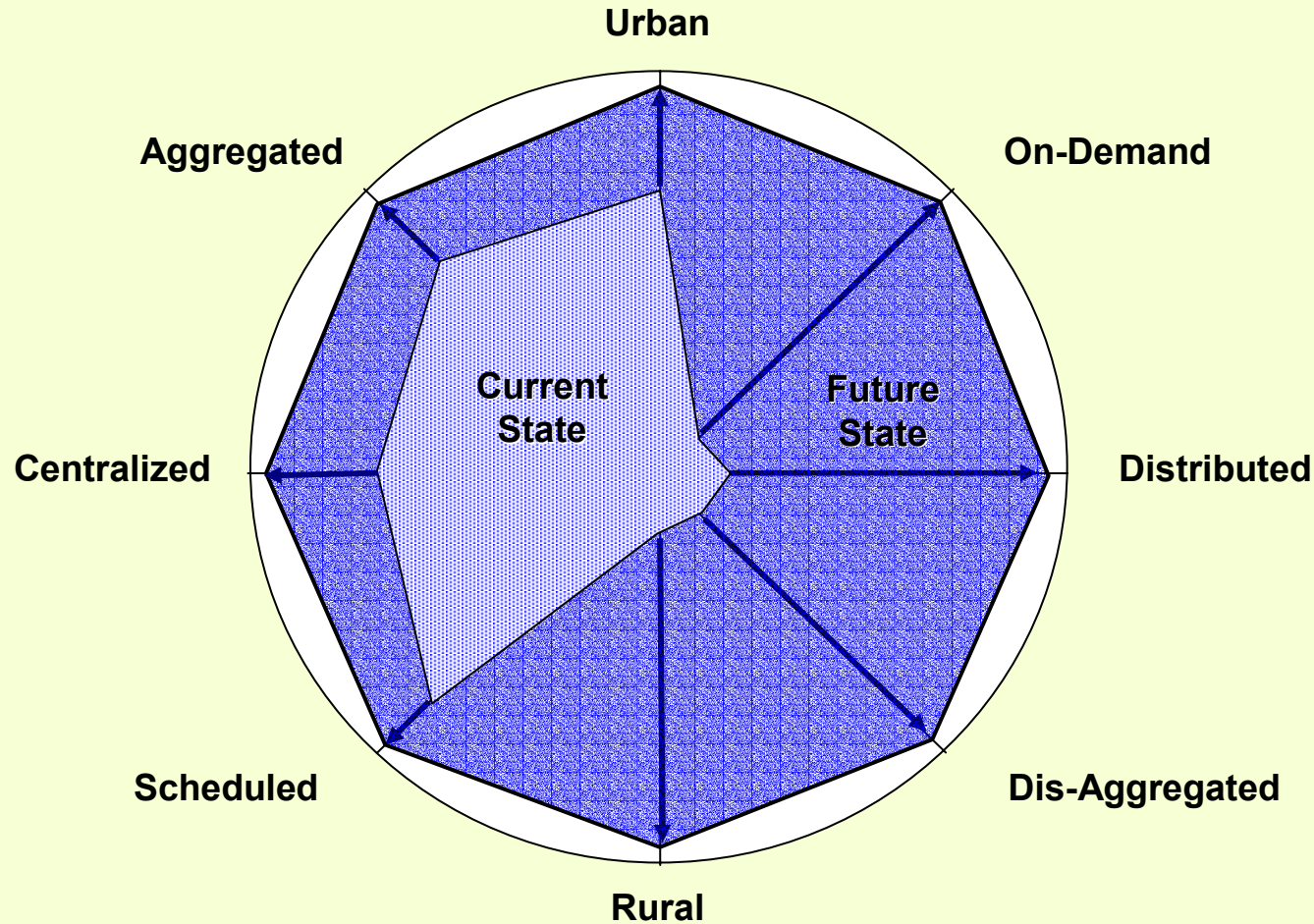


Primal Questions

1. What are the comparative mobility metrics (e.g., door-to-door speeds) for networks A, B, and C?
2. What are the optimal sizes, costs, performance of aircraft for these networks?
3. What are the comparative energy consumptions for optimized operations of these networks?
4. What are the comparative noise constraint optimization issues for these networks?
5. What are the comparative infrastructure costs at each layer of these networks?
6. What are the comparative degrees of resistance to disruptions of these networks?
7. What are the comparative degrees of vulnerabilities of these networks?
8. What are the percolation behaviors for “events” in these networks?
9. What changes occur within the network when one of the layers is fundamentally altered?
10. What topology of topologies (system of systems) expands the transformation concept space?



Notional Transformation Concept Space

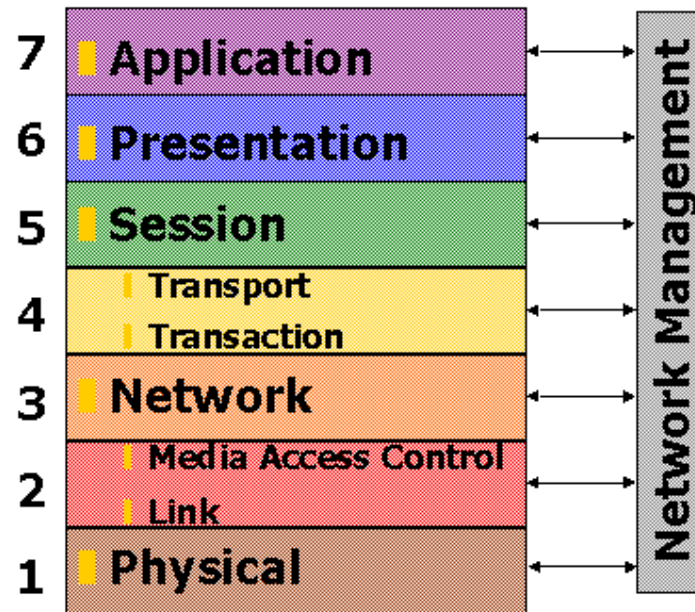


The vision includes expanding scalability along *all* dimensions.



ISO (or OSI) Stack Metaphor

LonTalk ISO-Model Protocol Stack



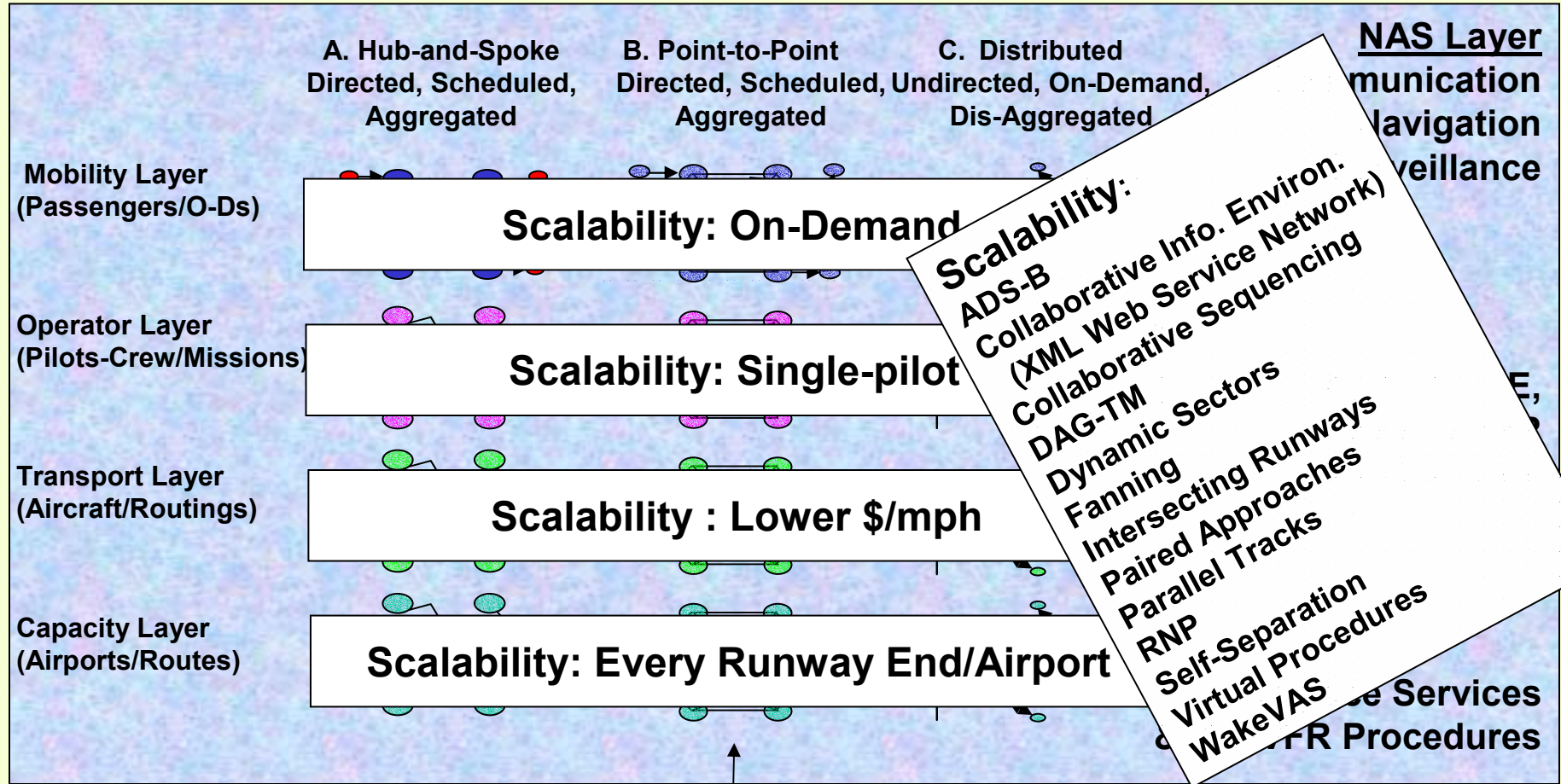
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Scalability for Air Transportation Networks

Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?



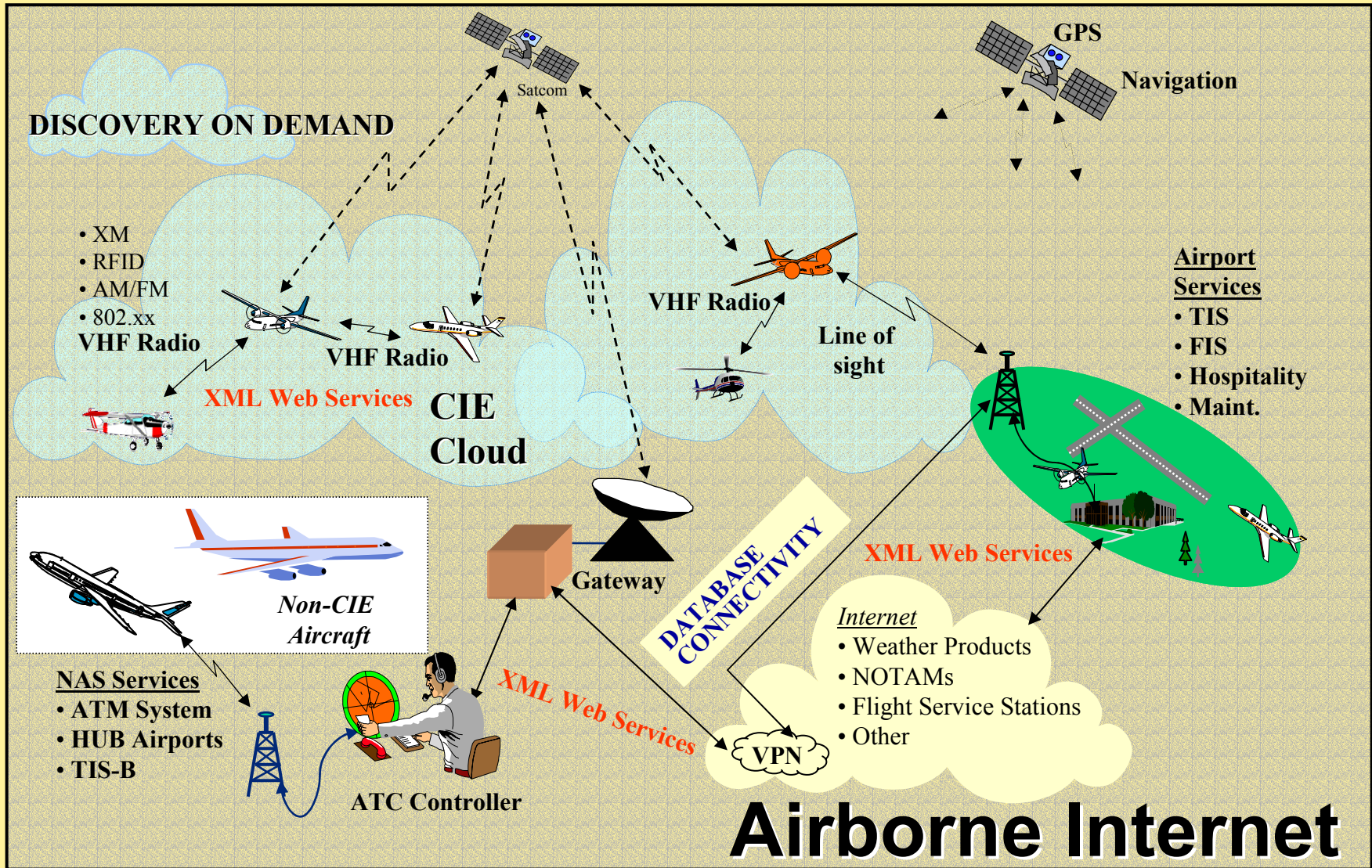
Policy Changes Enable Scalability of Business Stacks



Collaborative Information Environment

“Meet us in the cloud”

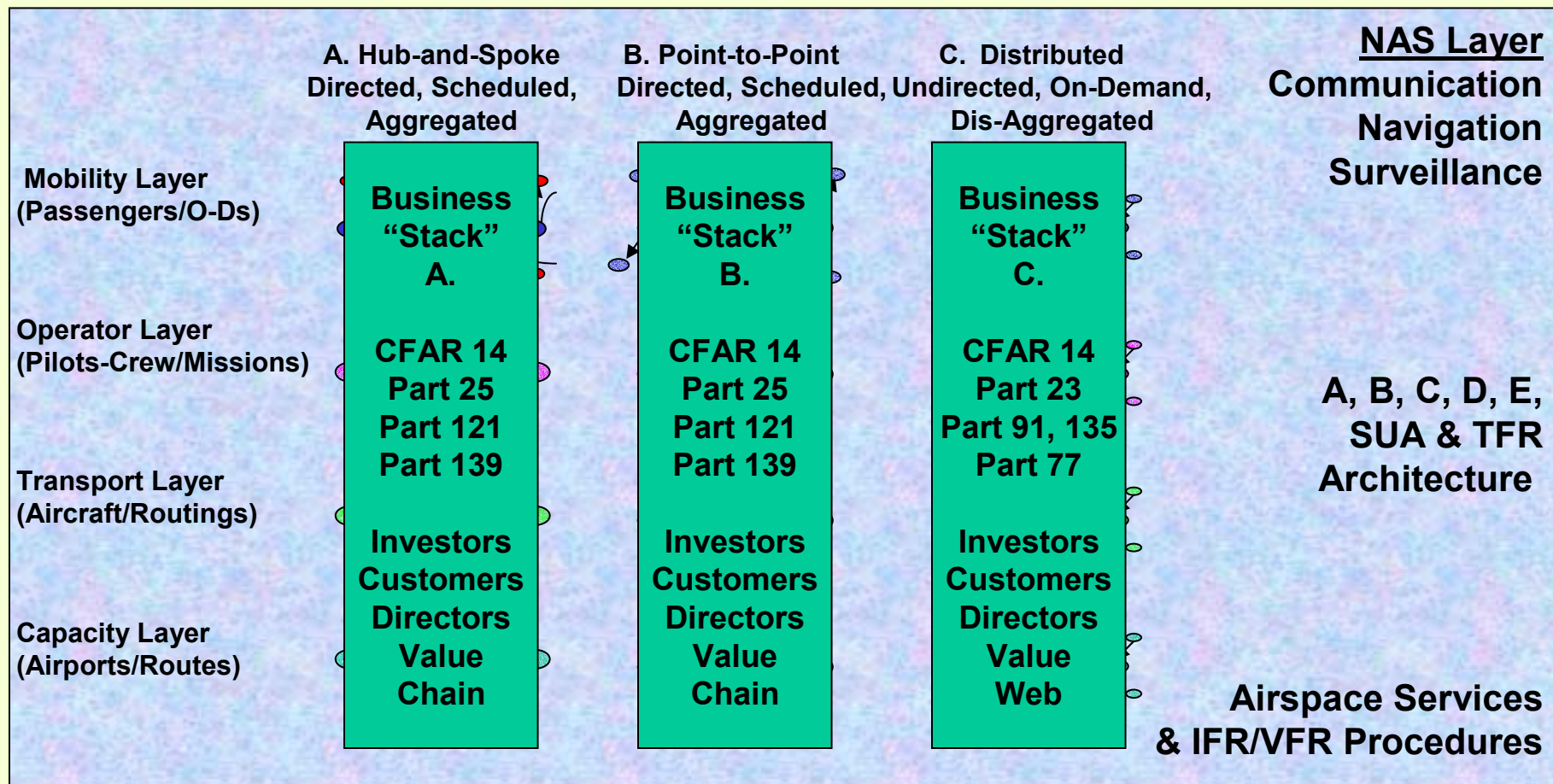
Original graphic courtesy of Computer Networks & Software, Inc.





Domain Layers for Air Transportation Networks

Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?





Summary

1. Transformation and scalability

- The Vision is to Expand Scalability Along *All* Dimensions of the Transformation Concept Space.

2. A *notional* air transportation network topology

- A layered system of networks offers a mental model for thinking about transformation.

3. Technologies and System Scalability

- Technologies and policies that enhance scalability are those that reduce friction, cost, and time.

***Modern developments in network theory
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complex, adaptive systems.***